A Coupled Model for Two-Phase Simulation of a Heavy Water Pressure Vessel Reactor

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Abstract : A Multi-dimensional computational fluid dynamics (CFD) two-phase model was developed with the aim to simulate the in-core coolant circuit of a pressurized heavy water reactor (PHWR) of a commercial nuclear power plant (NPP). Due to the fact that this PHWR is a Reactor Pressure Vessel type (RPV), three-dimensional (3D) detailed modelling of the large reservoirs of the RPV (the upper and lower plenums and the downcomer) were coupled with an in-house finite volume one-dimensional (1D) code in order to model the 451 coolant channels housing the nuclear fuel. Regarding the 1D code, suitable empirical correlations for taking into account the in-channel distributed (friction losses) and concentrated (spacer grids, inlet and outlet throttles) pressure losses were used. A local power distribution at each one of the coolant channels was also taken into account. The heat transfer between the coolant and the surrounding moderator was accurately calculated using a two-dimensional theoretical model. The implementation of subcooled boiling and condensation models in the 1D code along with the use of functions for representing the thermal and dynamic properties of the coolant and moderator (heavy water) allow to have estimations of the in-core steam generation under nominal flow conditions for a generic fission power distribution. The in-core mass flow distribution results for steady state nominal conditions are in agreement with the expected from design, thus getting a first assessment of the coupled 1/3D model. Results for nominal condition were compared with those obtained with a previous 1/3D single-phase model getting more realistic temperature patterns, also allowing visualize low values of void fraction inside the upper plenum. It must be mentioned that the current results were obtained by imposing prescribed fission power functions from literature. Therefore, results are showed with the aim of point out the potentiality of the developed model.

Keywords : PHWR, CFD, thermo-hydraulic, two-phase flow
Conference Title : ICNE 2015 : International Conference on Nuclear Engineering
Conference Location : Paris, France
Conference Dates : November 19-20, 2015

Open Science Index, Nuclear and Quantum Engineering Vol:9, No:11, 2015 publications.waset.org/abstracts/32717.pdf